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Date: July 23, 2004

To: Sue Sillick

From: Stuart Jennings

Re: Progress Report 4. *Evaluation of Organic Matter Addition and Incorporation on Steep Cut slopes, Phase II: Test Plot Construction and Performance Monitoring*

The fourth progress report of Phase II of the above referenced project is attached. The attached narrative describes the construction of research plots near Miles City, Montana on clay-rich and erodible parent material. Two sets of 5 plots, or a total of 10 plots, were constructed in early May near the I-94-U.S. Highway 12 interchange.

Monitoring of research sites near Happys Inn on U.S. Highway 2 was also initiated.

Quarterly Progress Report #4
For the period April 1, 2004 – June 30, 2004

EVALUATION OF ORGANIC MATTER ADDITION AND INCORPORATION ON STEEP CUT SLOPES

Phase II: Test Plot Construction and Performance Monitoring

Prepared For:

Montana Department of Transportation
P.O. Box 201001
Helena, MT 59620-1001

Prepared By:

Reclamation Research Unit
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July 2004

Task Analysis and Discussion

No activity occurred during the quarter on the project tasks: A (Literature Review), D (Equipment Identification), E (MDT Coordination Meeting), F (Pre-construction Meeting), or K and L (Year 2 and 3 Monitoring). As of the end of this quarter Tasks A, B, C, D, E, F, G and H are 100% complete. Two principal activities occurred during the past quarter: initial monitoring of the Happys Inn research site and construction of ten test plots at Miles City. Plot construction (Task H) is now 100% complete and the principal activity over the next 3 growing seasons will be monitoring of vegetation and erosion condition (Tasks J, K and L).

Task I Site Sampling

Samples collected from the Miles City research sites during the current quarter were submitted for laboratory analysis. Results from the analytical laboratory were received and compiled into the appended narrative.

Task J Year 1 Monitoring

Monitoring of the research plots near Happys Inn occurred on June 1 and 2, 2004. The plots exhibit outstanding vegetation growth on the treated plots. Images of the plots were e-mailed to Phil Johnson who later made a follow-up visit. Data was collected describing the vegetation and erosion condition of each plot. These data are appended to this progress report.

Task K Year 2 Monitoring

This task has not been initiated.

Task L Year 3 Monitoring

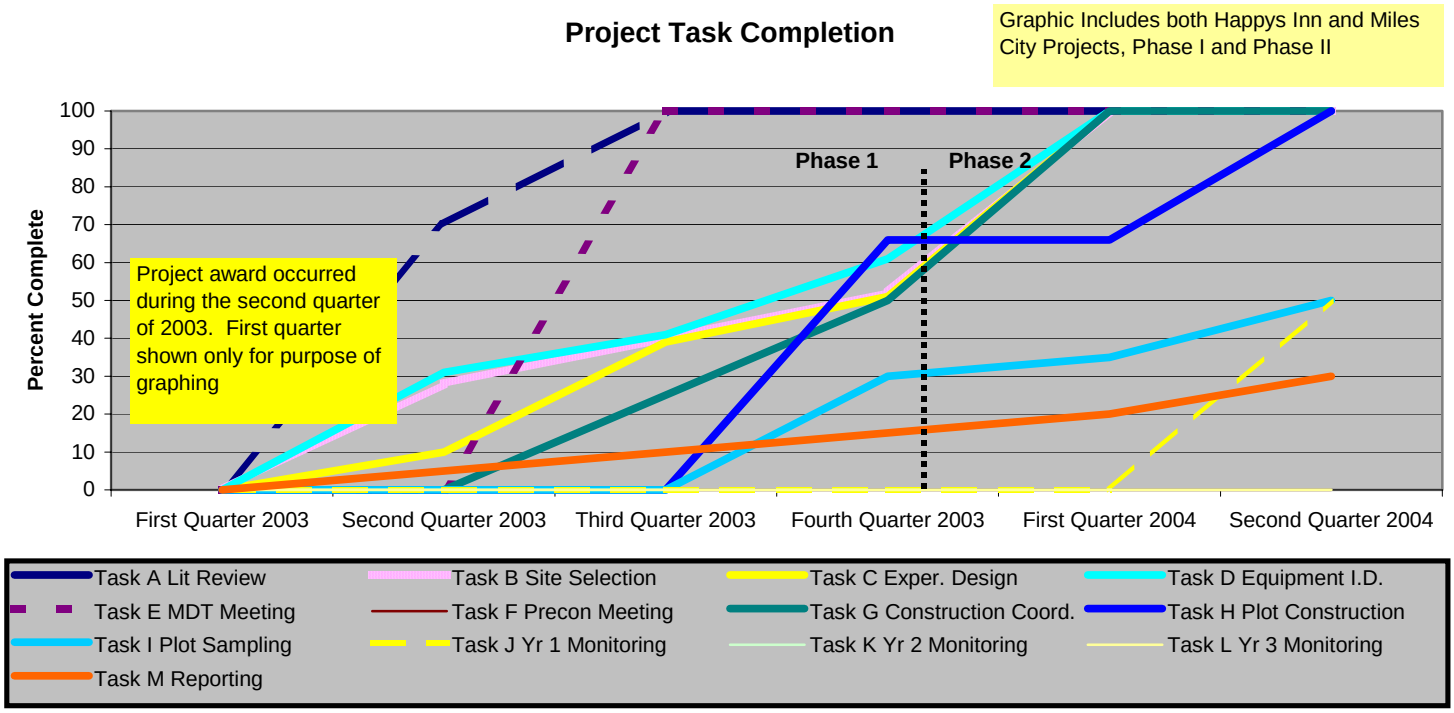
This task has not been initiated.

Task M Reporting

This fourth quarterly report satisfies the periodic reporting requirement of the contract. A Final Report will also be completed in 2006 summarizing the research findings. This report includes the Miles City plot construction narrative as well as the data from monitoring of the Happys Inn research site. These data will ultimately be compiled in the final report late in 2006.

Schedule and Degree of Completion—all research sites

Task Description	***Budgeted Total Phase II***	***Proposed Schedule***	***Actual Schedule***	***Degree of Completion***	***Estimated Expenditure during current quarter***
Task B Site Reconnaissance	$678	Q3, 2003	Q3 2003, and Q1 2004	100%	0
Task C Experimental Design	$407	Q4, 2003	Q4 2003, and Q1 2004	100%	0
Task G Construction Schedule Coordination	$377	Q3, 2003	Q1, 2004	100%	0
Task H Plot Construction	$36,087	Q4, 2003	Q4, 2003	100%	$14,596
Task I Site Sampling	$8761	Q4, 2003 and Q3 2005	Q4, 2003; Analytical results Q1, Q2 2004	50%	$2500
Task J Year 1 Monitoring	$13,083	Spring and Fall, 2004	NA	50%	$3000
Task K Year 2 Monitoring	$15,912	Spring and Fall, 2005	NA	0%	0
Task L Year 3 Monitoring	$16,065	Spring and Fall, 2006	NA	0%	0
Task M Reporting	$16,380	Quarterly and Final Report, Fall 2006	ongoing	30%	$2500



Review of the proposal for this project anticipated that all of the tasks (A-H) would be completed by the end of the State fiscal year on June 30, 2004. Further, the proposal anticipated that monitoring during year 1 (Task J) would be initiated, plot sampling would be 50% complete and reporting (Task M) would be on-going. The completed project work, therefore, very closely approximates the schedule and budget. The predicted project expenditure at the end of the State fiscal year was $50,841.38 the actual project expenditure was $56,192. While the actual expenses are approximately 10.5% ahead of the budgeted amount there is no compelling need for modification of the State FY budget. Additional work was accomplished during the period including construction of 5 additional plots at the Miles City site. This work was not anticipated in the original cost proposal. Substantial progress has also been made in preparation of the final report due in the 4th quarter of 2006 by completing write-ups of the plot construction narratives. Overall, the scope, schedule and budget appear to be in good alignment with slightly more work being completed during the first year than expected.

Problems and Resolution

A site was selected near Miles City on U.S. Highway 12 immediately east of the I-94 junction for implementation of the Eastern Montana clay/shale research plots. During construction of the plots, characteristics of the soil material were observed to be unrepresentative of shale and clay. It was determined in the field that the parent materials was some type of imported coversoil placed over the shale at the time of roadway construction. While the poorly vegetated condition

observed is consistent with the overall research objectives of using compost to provide for enhanced vegetation growth, the desire to select a clay-rich parent material remained. Phil Johnson (MDT) made the field decision to add an additional set of test plots nearby. The I-94/U.S. 12 junction and overpass was built using clay-rich fill material that has previously proven difficult to revegetate. The second set of test plots were constructed at this location approximately one-quarter mile away from the initial set of plots. The first problem created was that insufficient compost was ordered to constructed 2 sets (8 with compost) of plots. The plot size was reduced to accommodate the increase in plot number. Increasing the number of test plots requiring monitoring without a corresponding increase in budget created a second problem. A teleconference between Phil Johnson, Sue Sillick and Stuart Jennings occurred on May 17, 2004 to address the monitoring issue. It was decided that the budget may need to be increased at some time in the future to cover increased costs associated with monitoring. It was estimated that this budget increase would not exceed $5000. It was Sue Sillick's preference not to modify the budget until such time that additional funds were required, and depending on expenditures occurring over the next two years. It was Stuart Jennings perception that the budget may not require amendment subject to MSU's ability to control costs estimated in the original proposal. The addition of 5 extra test plots, therefore, may or may not impact the budget. This decision was subsequently deferred until later in the project, and contingent on the need for additional funding.

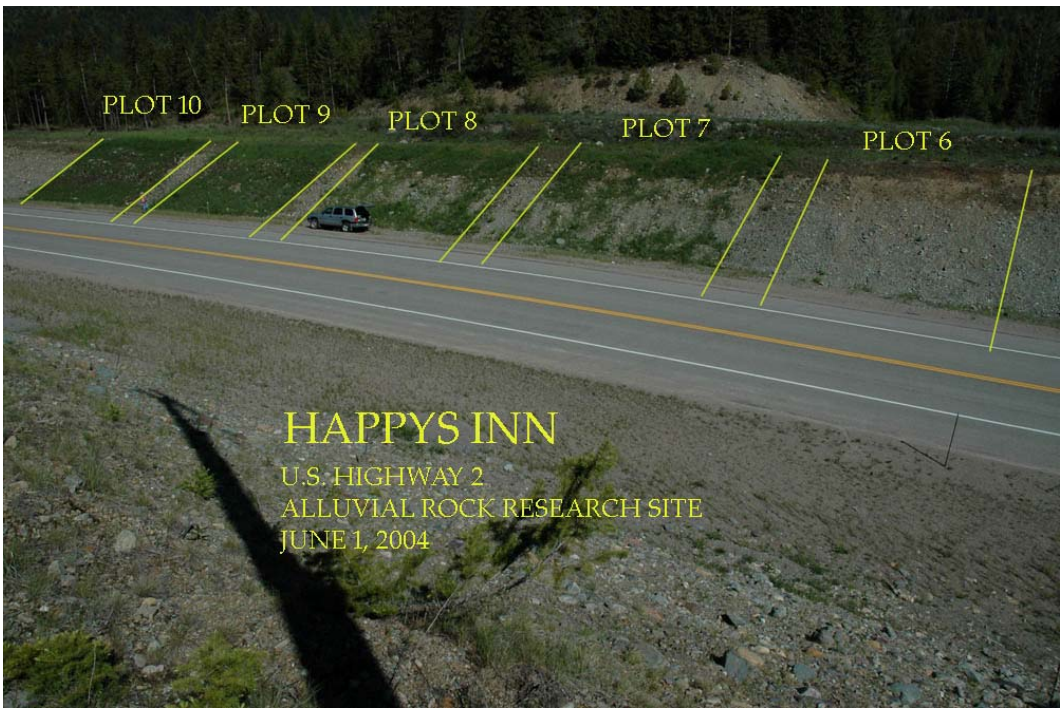
Accomplishments

- Construction of test plots occurred at the Miles City site. The attached narrative describes the activities associated with plot construction. Two VHS video tapes were submitted to MDT showing the plot construction activity. Digital video is also available.

- Analytical data representing the pre-treatment soil conditions observed at the Miles City research sites were compiled and are attached to this progress report. The data presented confirmed prior assumptions related to the expected harsh physical and chemical conditions associated with clay-rich shale parent material.

- Monitoring of the Happys Inn research sites was initiated. Each research site will be visited twice per year during 2004, 2005 and 2006. The spring monitoring trip to Happys Inn to monitor the 10 research plots constructed during the fall of 2003 occurred on June 1 and 2, 2004. Vegetation establishment on the treated plots has been excellent. Monitoring of the control plots (number 1 and 6) confirms some seedling germination, but poor plant vigor compared to the compost plots (see images below). The compost blankets (plots 4, 5, 9 and 10) revealed vigorous and uniform vegetation establishment compared to the incorporated compost plots (numbers 2, 3, 7 and 8). The 1 inch deep compost blanket (plots 4 and 9) appeared to provide the best performance in preliminary assessments.

PLOT 5
PLOT 4
PLOT 3
PLOT 2
PLOT 1
U.S. Highway 2
Glacial Silt Research Site
JUNE 1, 2004


PLOT 10
PLOT 9
PLOT 8
PLOT 7
PLOT 6
HAPPYS INN
U.S. HIGHWAY 2
ALLUVIAL ROCK RESEARCH SITE
JUNE 1, 2004

Fiscal Expenditure

Amount Spent by budget category:

Cost Category	***Spent prior to current quarter ($)***	***Spent during the current quarter ($)***	***Total spent to date ($)***
Labor and Benefits	$16,378	$10,155	$26,533
Operational Expenses	$3582	$1520	$5102
Subcontracted Services	$8037	$7155	$15,192
Indirect Charges	$5590	$3766	$9356
Total Spent	***$33,596***	***$22,596***	***$56,192***

Total Project Award $108,975 (*subject to modification during 2006 to provide for implementation of the test plots at Miles City—not to exceed $5000 additional—as required*)

Amount Remaining $52,783

Progress Report
Attachments

Miles City Test Plot Construction Narrative (to be inserted into final report)

1.0 INTRODUCTION

Successful steep slope reclamation associated with highway construction has proven problematic under a number of different geologic and climatic conditions. Failure to establish a self perpetuating vegetative cover has lead to increased maintenance costs and in a number of cases, storm water runoff water quality problems. The positive effects organic matter in the soil profile are widely known. Organic matter tends to enhance precipitation infiltration, water holding capacity, nutrient availability, soil structure and soil biota. The goal of research undertaken in this project is to provide a basis for practical guidelines to use of compost material on steep cut slopes for vegetation enhancement on several types of substrates and in two widely differing climatic regimes.

This research project was separated into two phases. Phase I consisted of two primary tasks: 1) a review of literature to determine probable optimum rates of organic compost addition to steep cut slopes, and 2) evaluation of potential equipment capable of applying and incorporating the compost to a maximum of 10.1 cm (4 in.) on 2H:1V slopes. Site reconnaissance of candidate field research sites for the second phase of the project also occurred. The Phase I final report was submitted to the Montana Department of Transportation in August 2003 and is available the Department's web site at:

http://www.mdt.state.mt.us/research/docs/research project/organic matter/final report.pdf

Phase II consists of two primary tasks: 1) evaluation of the efficacy of the application/incorporation equipment, and 2) qualitative measurement of vegetation condition and observations of erosional stability. Experimental plots constructed as part of Phase II are located at three field sites:

- Two sites located near Happys Inn, Montana consisting of very coarse alluvium (Mile Post 69 site) and fine grained lake bed sediments (Mile Post 77 site), and
- Two sites site on high clay soils in southeastern Montana.

Construction of the Happys Inn sites was completed during October 2003. A report detailing construction of these sites was included in the December 2003 project progress report, also available on the Montana Department of Transportation web site at:

http://www.mdt.state.mt.us/research/docs/research project/organic matter/progress dec03.pdf

This report details construction of the remaining two research sites near Miles City in southeastern Montana.

2.0 MILES CITY RESEARCH AREA

The Phase II Proposal for this project envisioned construction of the Eastern Montana site as part of the Colstrip South construction project on State Highway 39. Specifications for compost depth and tillage requirements were to be presented to the contractor who could then decide what equipment to use to most economically complete the project. Efforts to arrange incorporation of the research plots within this construction project were unsuccessful. An alternative site was selected at the junction of I-94 and U.S. Highway 12, approximately 4.8 km (3 miles) east of Miles City, Montana (Figure 1). Initial reconnaissance of this site was conducted March 31, 2004. Considerable effort was expended in an attempt to employ a private contractor for this work and these efforts were unsuccessful. The specialized equipment required and the small size of the research project are thought to be factors in the lack of interest from the private sector. The work was completed by Reclamation Research Unit staff and rented equipment as detailed in the following sections.

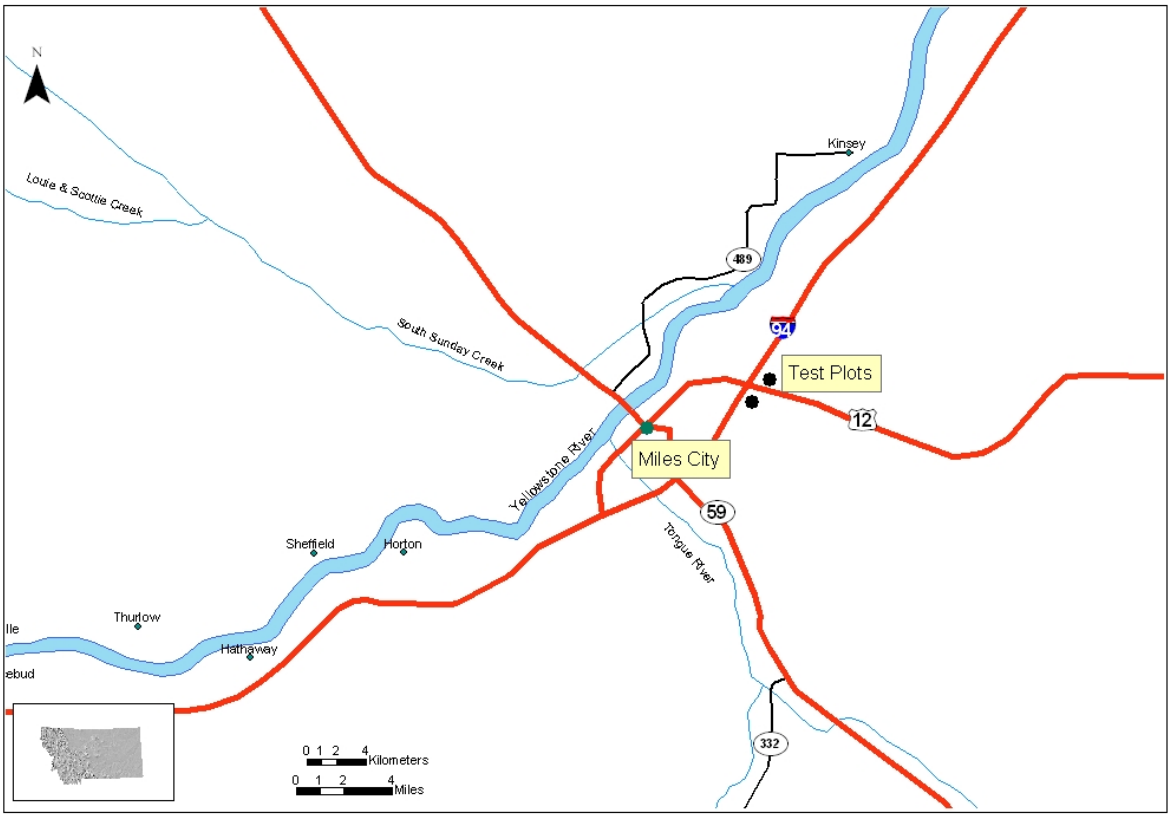


Figure 1. Miles City research area location.

2.1 Physiographic Conditions

The two Miles City sites are located on typical Fort Union Formation terrain characterized by rolling to dissected hills underlain by shale and sandstone. Elevations range from 707.1 m (2320 feet) at the Yellowstone River, 4.8 km (3 miles) west of the research area, to about 975.4 m (3200 feet) in the Government Hill area about 9.6 km (6 miles) east of the research site. The elevation in the immediate area of the research plots ranges from about 731.5 m (2400 feet) at the base of the eastbound I-94 exit ramp to 755.9 m (2480 feet) near the top of the east most research plots (11 through 15). All drainage from the research area flows directly to the Yellowstone River via several small un-named ephemeral drainages.

The only geologic unit exposed in the vicinity of the research plots area is the Tullock Member of the Fort Union Formation. A description of this generally flat lying unit states:

Light-yellow and light-brown, planar-bedded, very fine- to medium-grained sandstone interbedded with less dominant gray shale and mudstone, locally, with brownish gray well-indurated argillaceous limestone beds that may contain plant fragment molds. Locally lower part contains narrow, sinuous, steep-walled channel deposits less than 50 ft wide composed of brownish yellow, cross-bedded sandstone. Thickness of member 150 ft. (Vuke et. al., 2001)

Research plots 11 through 15 are located on a cut slope dominated by the gray shale noted above, with occasional indurated thin sandstone lenses that produced a few large (50 cm) angular boulders on the plots. A thin veneer of topsoil had been applied to a portion of the cut and was observed on plots 11 through 15 following tillage. This observation resulted in the additional construction of plots 16 through 20, as detailed below, on a fill slope composed of raw shale.

Research plots 16 through 20 are located on fill material taken from the cut slope where plots 11 through 15 are located. A thin, discontinuous surface layer of coarse wood chips had been applied to this area, apparently with little benefit towards establishment of vegetation. The chips exhibited little, if any, decomposition 10 years following application. The surface of this area is dominated by shale fragments with little weathering evident.

2.2 Climatic conditions

Climatic data is available from two stations near the research sites: 1) Miles City (Station 245685), and 2) Miles City FAA Airport (Station 245690). These stations are approximately 5.4 and 6.3 km southwest of the research sites respectively (Figure 1). Elevations at these stations (719.3 and 799.8 m, respectively) bracket the elevation of the research plots. The period of record for Station 245685 is January 1, 1893 through July 31, 1982. The record for Station 245690 extends from January 16, 1937 through the present. The overall amount and distribution of average monthly precipitation at the two stations is very similar, with the airport receiving slightly more total annual precipitation (34.2 versus 33.3 cm) likely due to the 80.5 m elevation difference between the stations (Figure 2). The annual distribution of precipitation is typical of

Eastern Montana. Approximately 75 percent of the precipitation occurs during the growing season from April through September with the month of June receiving the greatest amount. The October through March period is typically dry and in stark contrast to the Happys Inn sites which receive most of the annual precipitation during this period. Most precipitation in the November through April period occurs as snowfall with the 15 cm (6 inch) maximum accumulated snow depth occurring in February.

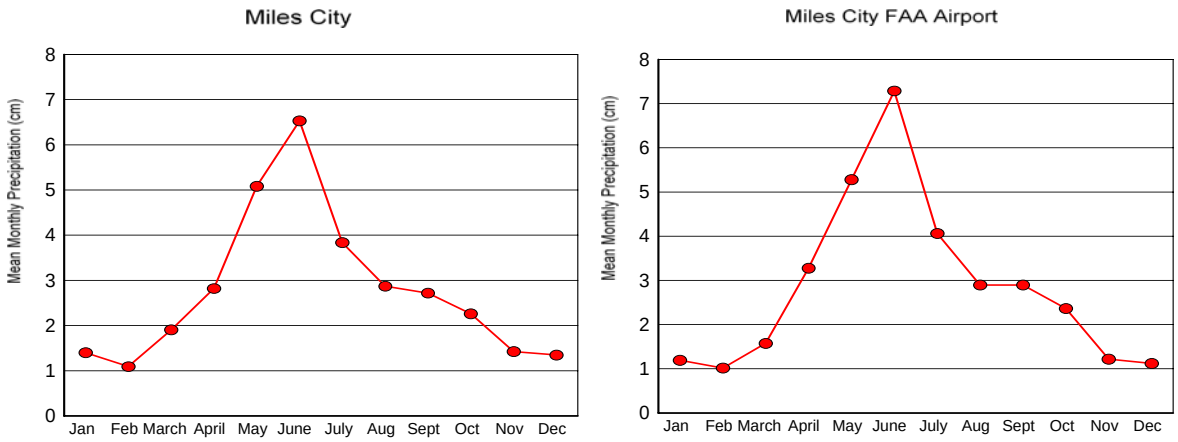


Figure 2. Monthly precipitation for NOAA stations 245685 (Miles City) and 245690 (Miles City FAA Airport).

The mean annual temperature at the two NOAA sites is 7.7 degrees C (45.9 degrees F). Average maximum temperatures range from -2.7 degrees C (27.1 degrees F) in January to 31.8 degrees C (89.3 degrees F) in July. Average minimum temperatures remain less than 0° C in the November through March period (Figure 3).

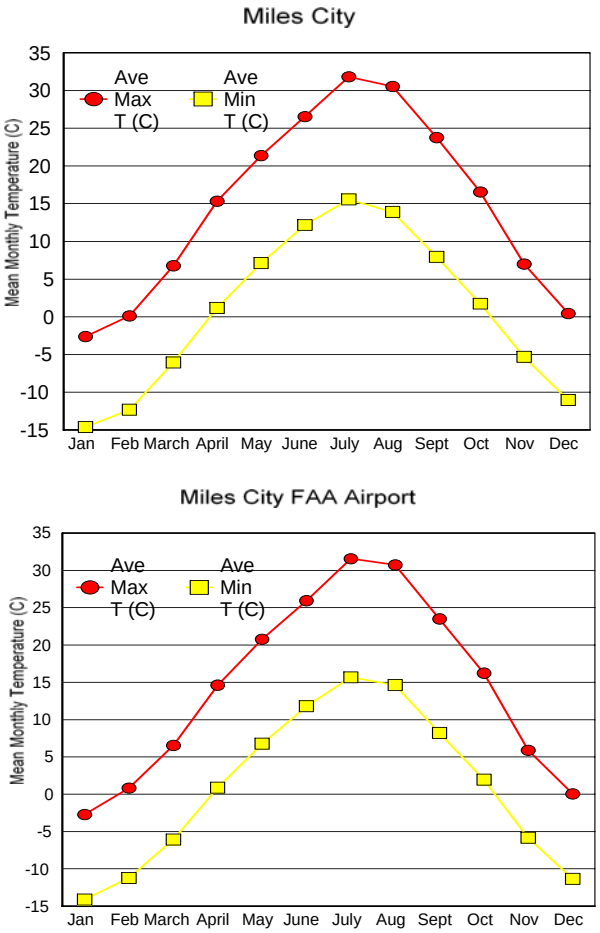


Figure 3. Mean monthly maximum and minimum temperatures for Miles City and Miles City FAA Airport climate stations.

The MAPS program (Caprio et. al., 2001) calculated annual potential evapotranspiration (PET) is 79 cm (31 inches). The April through September potential evapotranspiration (PET) of 74.9 cm (solar unit method) exceeds precipitation during this period (24.8 cm) by nearly 300 percent. The month of July exhibits the greatest PET (20 cm) indicating a potential deficit of nearly 16 cm between available precipitation and PET (Figure 4). While the bulk of the annual precipitation occurs during the growing season, adequate precipitation is clearly the primary limiting factor for vegetation production at this site.

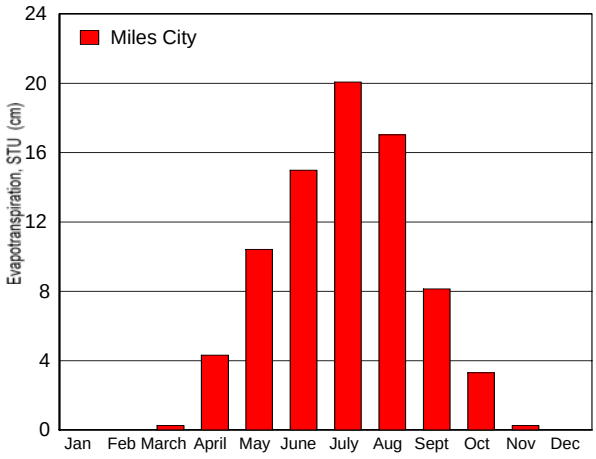


Figure 4. Mean monthly potential evaporation for the Miles City research area. Values determined through MAPS program by Caprio (1971) solar-thermal unit method.

3.0 EXPERIMENTAL DESIGN

A total of 20 research plots have been established during Phase II of this project and represent 4 different types of substrates and two greatly differing climatic regimes. Treatments include:

- Tillage and broadcast seeding only (controls);
- 2.5 cm compost application incorporated to 10 cm, broadcast seeding;
- 5.1 cm compost application incorporated to 10 cm, broadcast seeding;
- 2.5 cm compost application (blanket), broadcast seeding; and
- 5.1 cm compost application (blanket) with broadcast seeding.

3.1 Happys Inn Experimental Design

The experimental design for the Happys Inn sites is detailed in the December 2003 progress report for this project and is available at the Montana Department of Transportation web site as noted above.

3.2 Miles City Experimental Design

Ten research plots have been established in the Miles City research area (Figure 5). The original study plan included only one site to be comprised of five plots. Two factors encountered during construction of the Miles City plots resulted in a notably modified experimental design. These included:

- After tillage was initiated on the cut slope where plots 11 through 15 were located, it was apparent that some topsoil had been placed on this cut slope, and
- Vendor equipment breakdown prevented delivery of the entire required compost volume requiring acquisition of additional compost from a second vendor.

The topsoiled cut slope generally exhibited poor vegetation cover and was a suitable test site for the compost application. It did not however, provide a good test for application of compost on raw geologic materials. The I-94 off ramp fill was composed of raw shale with essentially no vegetative cover and provided an opportunity for construction of a second set of plots. The resulting plot sizes were reduced to fit the volume of compost ordered which resulted in 186 m^2 (2000 ft^2) plot sizes that were nearly identical to those constructed at Happys Inn.

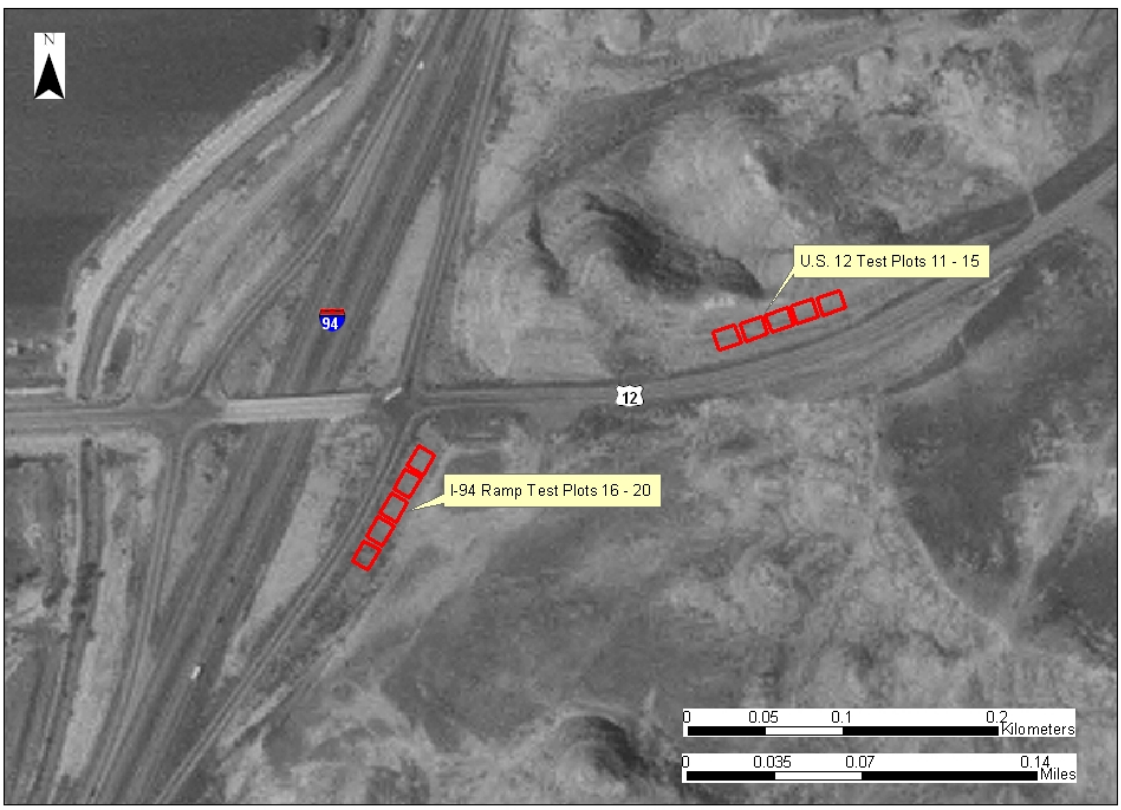


Figure 5. Miles City research plot locations.

The vendor loading equipment problems resulted in delivery of only 45.9 m^3 (60 cy) of Earth Systems compost rather than the 58.9 m^3 (77 cy) ordered, with delivery at 11:00 pm the night before application was to begin. There was insufficient time for shipping an additional load of Earth Systems compost. Arrangements were made for the blower truck to load the additional 13 m^3 (17 cy) at Rocky Mountain Compost in Billings, Montana. To maintain the integrity of the experimental design, plots 16 through 20, located on the off-ramp shale fill, were split vertically with Rocky Mountain compost applied to the southwest side and Earth Systems compost applied to the northeast side (Figure 6). Even with the acquisition of the 13 m^3 (17 cy), compost application was short on plot 12, the last plot constructed. This plot was divided vertically with only the west half receiving compost. The experimental design was identical to plots constructed at the Happys Inn sites and included four treatments and a control at each site (Table 1).

Figure 6. Plots 19 (compost blanket) and 20 (incorporated compost), I-94 off-ramp area, showing Rocky Mountain compost on the left (light-colored) and Earth Systems compost on the right (dark-colored).

Table 1. Plot treatments for the Miles City research sites.

Site	Plot Number	Treatment	Mean Overall Gradient (%)	Mean Slope Length (m)
Miles City Cut Slope Shale Dominated Material with approximately 5 cm loam/sandy loam soil	11	2.54 cm compost, incorporated with chisel tipped tiller	30.5	12.2
	12	5.08 cm compost, incorporated with chisel tipped tiller (no compost on east ½ plot)	32.0	12.2
	13	5.08 cm compost blanket	33.5	12.2
	14	Control, no compost, chisel plowed	33.5	12.2
	15	2.54 cm compost blanket	33.5	12.2
Miles City Fill Slope Shale Fragment Fill	16	5.08 cm compost, incorporated with chisel tipped tiller	30	15.2
	17	2.54 cm compost blanket	33.5	15.2
	18	Control, no compost, chisel tipped tiller	36.5	15.2
	19	5.08 cm compost blanket	37.5	15.2
	20	2.54 cm compost, incorporated with chisel plow	39.5	15.2

4.0 RESEARCH PLOT CONSTRUCTION

The following subsections describe the implementation of study sites at Miles City Highway 12 (cut) slope and Miles City I94 (fill slope).

4.1 Plots 11 Through 15

The experimental design for the Miles City research site delineated a total of 5 plots to be located on the south aspect cut slope immediately east of the eastbound off ramp from Interstate Highway 94 at Mile Post 141 (Figure 7). Plot construction was initiated on April 27, 2004. Plots 11 through 15 were located and staked using a 15.2 m (50 ft) by 22.9 m (75 ft) plot size. The centers of each plot were located and composite soil samples collected. Following sample collection, all plots were tilled across the slope.

Compost was applied to the treatment plots on April 28, 2004 following adjustment of the plot boundaries to accommodate a second set of plots. The plots were downsized by moving the top and bottom boundaries equal distance, thus maintaining the sample location at the center

of each plot. Plot width remained 15.2 m, with a 3.0 m (10 ft) buffer area between plots and a final constructed slope length of 12.2 m (40 ft). As previously noted, there was insufficient compost volume to completely cover Plot 12 to the desired 5.08 cm thickness. Only the west half of this plot received compost. Soils on plots 11 through 15 were fine to medium textural class with low coarse fragment content (Table 2). A silt fence was installed the entire length of the site (88.4 m) up-slope from the top of the plots to control run-on sedimentation from areas above the research plots.

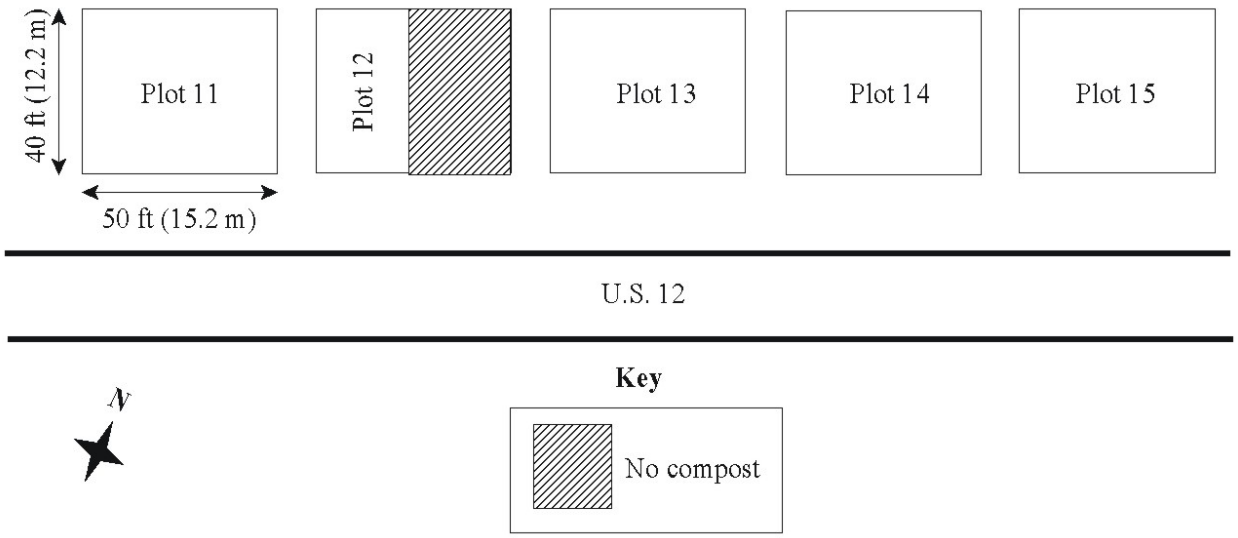


Figure 7. Research plot layouts at the U.S. Highway 12 cut slope site.

Table 2. Highway 12 cut slope preconstruction physical site characteristics.

Plot	Treatment	Mean Overall Gradient (%)	Rock Content > 2mm (%, mass basis) [1]	USDA Textural Class[2]
11	2.54 cm compost, incorporated	30.5	0.93	clay loam
12	5.08 cm compost, incorporated (compost on west half only)	32.0	4.04	clay loam
13	5.08 cm compost blanket	33.5	1.98	Loam
14	Control, no compost	33.5	1.45	Loam
15	2.54 cm compost blanket	33.5	0.92	Loam

[1] ASTM D422-63
[2] ASA/SSSA, 1986: Method 15-5 Modified Day Hydrometer Method

4.2 Plots 16 through 20

Research plots 16 through 20 were 12.2 m (40 ft) wide with a slope length of 15.2 m (50 ft) (Figure 8). Plots were separated with 3.0 m (10 ft) buffer strips. All plot areas are 185.8 m^2 (2000 ft^2). This site was characterized by fine textural class soils and high coarse fragment content (Table 3). Nearly all of the coarse fragment content consisted of un-weathered shale bedrock fragments. Each of plots 16 through 20 were split into 2 subplots, with Rocky Mountain compost applied to the south west subplot portion and Earth Systems compost applied to the northeast subplot portion.

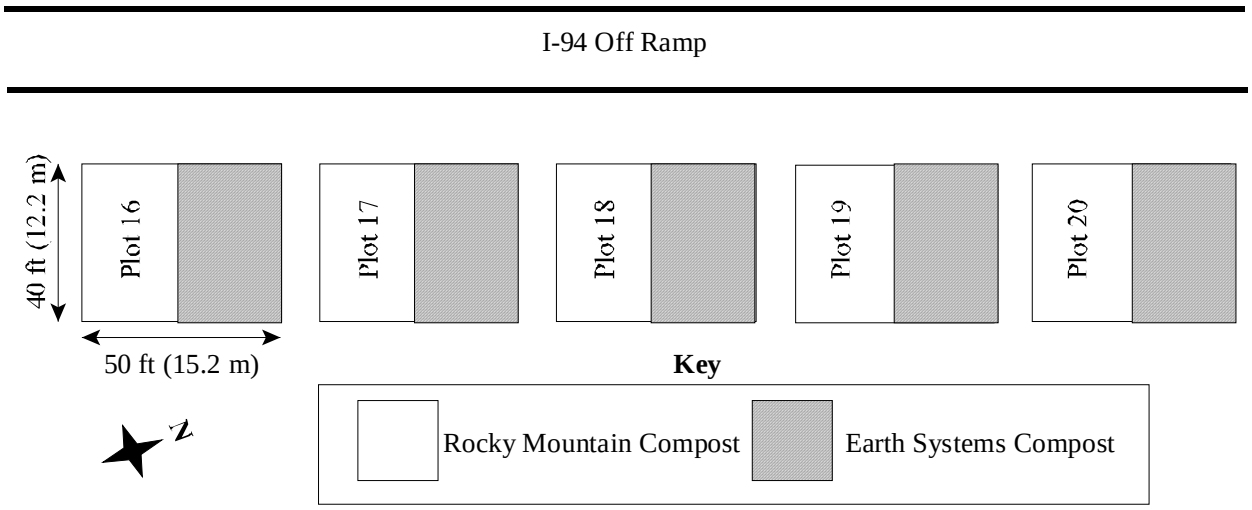


Figure 8. Research plot layouts at the I-94 fill slope site.

Table 3. I-94 fill slope preconstruction physical site characteristics.

Plot	Treatment	Mean Overall Gradient (%)	Rock Content > 2mm (%, mass basis) [1]	USDA Textural Class[2]
16	5.08 cm compost, incorporated	30	17.45	Clay
17	2.54 cm compost blanket	33.5	44.06	Silty clay
18	Control, no compost	36.5	16.48	Clay loam
19	5.08 cm compost blanket	37.5	27.03	Clay loam
20	2.54 cm compost, incorporated	39.5	64.65	Clay

[1] ASTM D422-63
[2] ASA/SSSA, 1986: Method 15-5 Modified Day Hydrometer Method

4.3 Seeding

All plots at both Miles City sites were seeded with the same seed mix (Table 4) that was obtained from Bruce Seed Farm, Inc. located near Townsend, Montana. Seed was applied using a hand operated broadcast seeder at a total rate of 1.81 kg per plot. This rate is the approximate equivalent of 97 kg/ha. Seeding methodology was identical to that used at the previously constructed Happys Inn sites:

The seed was applied in two applications, the first on bare substrate and the second following application of 1.3 cm of compost over the first seed application. The remaining compost was applied over the second seed application.

The seeding scenario acknowledges the fact that a portion of the applied seed will be placed deeper than desired and therefore this portion may have poor emergence. No noxious or restricted weed seed was found in the seed mix. Since no compost was applied to the control plot, seed was applied by a hand broadcast seeder directly to the mineral soil following tillage.

Table 4. Seed mix species used at the Miles City research sites.

Species	Common Name[1]	Variety	Percent of Mix (*pure live seed* basis)
Elymus trachycaulus ssp. trachycaulus	Slender Wheatgrass	Pryor	12.31
Elymus hoffmanii	Hybrid Wheatgrass	Newhy R/S	18.10
Pascopyrum smithii	Western Wheatgrass	Rosana	18.77
Elymus	Wildrye, Beardless	Shoshone	17.92
Sporobolus airoides	Alkali Sacaton	V.N.S.	6.43
Cleome serrulata	Bee Plant, Rocky Mountain	V.N.S.	12.07
Astragalus cicer	Cicer Milkvetch	Lutana	6.64
Ericameria nauseous ssp. Nauseosa	Rubber Rabbitbrush		2.50
Sarcobatus vermiculatus	Black Greasewood		2.50

[1] Seed label contained only common name and variety.

4.4 Compost Mixing

Compost was mixed into the appropriate test plots using an AEBI tractor pulling a chisel plow. The AEBI tractor is specifically designed for operation on steep slopes. Tillage activity occurred both on the contour and down the slope, well within the rated capabilities of the AEBI tractor. Two incorporation passes were made to mix the compost into the upper 10cm (4 inches) of the soil. An initial tillage pass was made pulling the plow downslope followed by a final tillage pass on the contour. A total of 2 tillage passes occurred at right angles to one another. The final tillage pass on the contour imprinted the slope with furrows as technique for retarding storm water runoff. A preliminary evaluation of the effectiveness of the methods used to incorporate compost suggests that while incorporation was relatively good, mixing was not as thorough at the Miles City sites as it was at the Happys Inn sites. The compost mixing with the AEBI TT88 tractor/Ford tiller implement combination was not as complete as that achieved using the LMC snowcat at the Happys Inn sites probably due to the considerable additional mixing achieved by the snowcat grousers, but it was deemed adequate to sufficiently incorporate the compost to minimize erosion of the material from both wind and water. Both compost and soil were clearly discernable following the two tillage passes at 90 degrees.

4.5 Miles City Equipment Evaluation

The equipment utilized for this study included:

1. Express Blower (Rexius) blower truck model EB-30;
2. AEBI Terratrac model TT88 with optional category 1/2 standard agricultural 3-point hitches (front and back); and
3. A Ford 3 m wide 3-point mounted, spring shanked tiller with nine chisel points.

The performance of this equipment is discussed in the following subsections.

4.5.1 Blower truck

The blower truck utilized for the Miles City plot construction was the same unit used for the Happys Inn sites (Figure 9). No problems were encountered using two additional compost sources that exhibited two very different moisture contents. Production rates were similar to that chronicled at the Happys Inn sites.

Figure 9. Express Blower (Rexius) blower truck model EB-30 applying Earth Systems compost to Plot 17.

4.5.2 AEBI Terratrac TT88 Steep Terrain Tractor

The tractor employed for this work was an older (1990) AEBI Terratrac model TT88 equipped with a hydrostatic drive (Figure 10). This unit was rented from the Bridger Bowl Ski Area near Bozeman, Montana where its main use is mowing ski runs. The Phase I report for this research project identified the AEBI tractors as good candidates for compost incorporation on steep cut slopes. The Phase I report contains a listing of all current and past AEBI Terrratrac models produced. The TT88 used shares the dual 3-point system and dual PTOs (front and back) common to most Terratrac models, had an EROPs type enclosed cab, and a 44 kW (60 hp) diesel engine. While the slope steepness of the Miles City research plots fell somewhat short of the desired 50 percent, the abilities of the TT88 were not seriously challenged working on these plots (30 to 40 percent range). Tillage both across and up-down slopes was completed easily. Following adjustment of tire pressures to meet that recommended by AEBI, engagement of the differential locks was unnecessary. There was little problem turning at will on-slope. While this unit performed very well at the Miles City sites, it would likely have had difficulties at the Mile Post 69 site near Happys Inn that was composed of loose cobble, boulders and gravel. The only difficulty noted during construction of the Miles City plots was controlling the tillage implement till depth when working across the slope and encountering small gullies. When these features were traversed, the tractor would nose down when entering, which tended to pull the 3-point mounted cultivator out of the ground, and when exiting the gully the cultivator tended to be pushed down. These operating characteristics would be similar to any 3-point systems and it was controllable by constantly monitoring the tillage depth when crossing these features. The 3-point system allowed complete maneuverability on slope. Tillage speeds of several km/hr were obtainable both across and up-down slopes.

Figure 10. AEBI Terratrac TT88 .

4.5.3 Ford Spring Shanked Tiller

The Ford tiller used for this work had 9 shanks mounted at 0.30 m (1 foot) centers. All shanks were spring-loaded which allowed passage over several large boulders encountered when tilling plots 11 through 15. All shanks were equipped with chisel points. All initial plot tillage was across the slope. Compost mixing was initially up-down the slope followed by a second pass across the slope. The AEBI TT88 had little difficulty obtaining the desired 10.2 cm (4 inch) tillage depth and was capable sinking the shanks 0.3 m (1 foot), especially when tilling down slope.

Figure 13. Ford spring-shanked tiller on Plot 20 (Rocky Mountain compost in foreground, Earth Systems material in background).

4.5.4 Equipment Performance Summary

As noted during the construction of the Happys Inn sites the blower truck utilized for this study has the capability to apply compost or similar materials to nearly any slope up to a steepness at which the applied materials will slough off due to gravity. The blower has sufficient power to blow compost through at least 100 m of hose and likely considerably farther. The unit had no difficulty blowing either wet (Earth Systems) or dry (Rocky Mountain Compost) materials. A more detailed description of the performance of this unit can be found in the December 2003 progress report detailing the construction of the Happys Inn sites. The factory specification for the unit used (EB-30) suggests full-scale application rates could be double the rates at which the compost was applied to the research plots. Highway construction contractors will have to evaluate this type of equipment as they would any other: production versus cost. The blower trucks will be capable of applying compost where other means are lacking or are inefficient.

The use of AEBI tractors for tillage on steep slopes similar to those at the Miles City plots is viable. It is highly likely the TT88 could perform well on the shale dominated materials up to at least a 50 percent slope. Units with four wheel steering (TT70, TT70S, TT75, and TT270) would no doubt enhance productivity by allowing tighter turning. The four-wheel steer may also increase control while tilling across slope. The performance of this unit on sites that contain abundant cobble and boulders is unknown. Conditions similar to those encountered at the MP69 site near Happys Inn would at best present a number of control problems and in the worst case, insufficient traction could prevent traverse up-slope.

5.0 SAMPLING AND ANALYSES

Sampling protocol for the Miles City sites was identical to that used for the Happys Inn sites. Three part composite soil samples were collected from each plot prior to any tillage. Composite compost samples were collected prior to application.

5.1 Soil Samples

A single composite soil sample was collected from each plot. All samples were collected using identical methodology. The center of each plot was located and from this point, three subsample sites were located at 120 degree intervals on a 3 m radius, with one leg directly down-slope. All samples were collected by trenching the soil pit wall to a depth of 10.2 cm. Each sample consisted of a 7.6 liter (2 gallon) plastic sample bag. One duplicate soil sample (Plot 13) was collected for the 10 natural samples. Samples were analyzed for numerous parameters including pH, specific conductance (SC), sodium adsorption ratio (SAR), N, P and K, organic matter (OM), C:N ratio, coarse fragment content, and soil textural class (Table 5).

Table 5. Soil sample analyses.

Plot	Mg[1] mg/L	Na[1] mg/L	Ca[1] mg/L	EC[2] (dS/m)	pH[3]	SAR[1]	NO_3-N[4] mg/kg	P[5] mg/kg	K[6] mg/kg
11	14	474	48	2.02	9.0	15.5	16.7	4.4	316
12	49	1410	135	5.09	8.5	26.4	21.3	3.4	148
13	16	428	52	1.51	8.9	13.3	4.9	5.0	156
13D	40	600	112	2.82	8.6	12.4	5.0	3.7	148
14	11	224	31	1.02	8.9	8.8	3.3	3.0	166
15	15	157	31	0.87	8.8	5.8	4.6	3.7	180
16	340	3350	452	10.10	7.8	29.0	163.6	14.3	232
17	94	2170	284	6.3	8.3	28.5	84.1	12.1	236
18	25	1340	82	4.82	8.6	33.2	78.5	6.2	202
19	46	1760	175	6.07	8.4	30.6	62.2	5.3	170
20	28	1350	91	4.89	8.3	31.8	87.5	4.4	250

[1] ASA/SSSA, 1982: Methods 10-2.3, 10-3.4 (cations analyzed by Atomic Absorption Spectrometer-AAS)
[2] ASA/SSSA, 1982: Methods 10-2.3, 10-3.3
[3] ASA/SSSA, 1982: Methods 10-2.3, 10-3.2
[4] ASA/SSSA, 1982: Methods 33-8.2, 33-8.3
[5] ASA/SSSA, 1982: Method 24-5.4
[6] ASA/SSSA, 1982: Method 9-3.1, modified (extract diluted in 0.5 % La_2O_3 with1% HCl & analyzed AAS)

The soil analyses indicate that while the two Miles City sites are generally similar, the I-94 fill site exhibits more harsh soil conditions than the Highway 12 cut area. It has higher mean SAR (30.6 versus 14.0, respectively) and higher mean EC (6.4 versus 2.1 dS/m). The I-94 site also has higher mean nutrient concentrations for N (95.2 versus 10.2 mg/kg), P (8.5 versus 3.9 mg/kg), and K (218 versus 193 mg/kg).

5.2 Compost Samples

Compost for this project was obtained from two sources: Earth Systems near Church Hill, Montana, and Rocky Mountain Compost in Billings, Montana. It was not the intent of the experimental design to obtain compost from two different suppliers. Loading equipment problems at a vendor for the Earth Systems compost prevented delivery of the entire desired compost volume and an alternative source had to be found while plot construction was underway. Plots 16 through 20 received both types of compost which was not mixed. These plots were split into subplots with one of the two types of compost applied to each subplot (see Figure 8).

Compost analyses indicated that notable differences exist between the two types of compost:

- Earth Systems material exhibited notably higher EC 4.31 versus 1.24 dS/m),

- Higher total carbon (22.1 versus 15.3 percent),
- Higher total nitrogen (1.44 versus 0.55 percent, and
- Higher moisture content (37.7 versus 19.7 percent).

The C:N ratio of the Earth Systems material (as calculated from total N by combustion) was 15.3 while the corresponding value for Rocky Mountain Compost was 27.8.

Table 6. Compost sample analyses.

Compost Source	**pH[1]** (su)	**EC[2]** (dS/m)	**Total C[3]** (%)	**Total N[4]** (%)	**H_2O[5]** (%)	**Organic Matter** (%)
Rocky Mountain Compost	9.0	1.24	15.3	0.55	19.7	25.8
Earth Systems Compost	9.1	4.31	22.1	1.44	37.7	23.3

[1] TMECC method 04.11 (U.S. Department of Agriculture and The United States Composting Council, 2001)
[2] TMECC method 04.10
[3] TMECC method 04.01-A
[4] TMECC method 04.02-D
[5] TMECC method 03.09, ASA/SSSA 21-2.2 (1986)
[6] TMECC method 05.07

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APPENDICES

Appendix A-1
Analytical Data

Sample	> 2 mm Container Tare (g)	Container Tare plus all (g)	> 2 mm (g)	Container tare plus > 2mm fraction (g)	% Rock (mass)
Plot 11	17.21	815.05	7.44	24.65	0.93
Plot 12	17.25	815.87	32.2	49.55	4.04
Plot 13	16.39	933.81	18.21	34.60	1.98
Plot 13D	16.41	836.55	12.30	28.71	1.50[1]
Plot 14	17.27	784.55	11.15	28.42	1.45
Plot 15	16.39	768.80	6.91	23.30	0.92
Plot 16	17.24	762.44	130.02	147.26	17.45
Plot 17	16.48	754.56	325.22	341.70	44.06
Plot 18	17.32	768.55	123.79	141.11	16.48
Plot 19	16.42	760.16	201.00	217.42	27.03
Plot 20	102.35	669.19	366.49	468.84	64.64[2]

1 Relative Percent Difference = 27.6 %
2 Highly aggregated

Physical characteristics of soil substrates prior to construction of research plots near Miles City, MT.

Sample I.D.	Sand %	Silt %	Clay %	Saturation Percentage (% H_2O)	Texture
Plot 11	28	43	29	50.2	clay loam
Plot 12	28	43	29	74.2	clay loam
Plot 13	46	35	19	34.2	loam
Plot 13D	44	35	21	36.9	loam
Plot14	42	39	19	35.4	loam
Plot 15	38	43	19	38.2	loam
Plot 16	22	33	45	86.5	clay
Plot 17	16	39	45	114.0	silty clay
Plot 18	24	39	37	110.4	clay loam
Plot 19	26	41	33	84.4	clay loam
Plot 20	14	39	47	159.8	clay

Appendix A-2
Vegetation Monitoring
Happys Inn Research Sites
June 2004

Table A.2.1 Vegetation Monitoring, U.S. Highway 2, Milepost 76, Middle Thompson Lake (plots 1-5) and Milepost 69, Loon Lake (plots 6-10), June 2004. The Middle Thompson Lake plots are constructed on glacial silt while the Loon Lake plots are constructed on alluvial rock.

Plot Number	Frame Number	Tape Distance (feet)	Plant stems/ Frame (20x50 cm)	Aerial Cover		Comments
				% grass	% forbs	
1	1	14	15	1	0	1 clover?
	2	16	18	1	0	
	3	18	29	1	0	
	4	25	20	1	0	
	5	33	14	1	0	
	6	42	10	<1	0	
	7	45	19	1	0	
	8	53	3	<1	0	
	9	55	2	0	0	1 forb
	10	56	3	<1	0	
2	1	18	11	7	0	
	2	25	18	20	0	
	3	26	14	15	0	
	4	35	9	15	2	clover
	5	36	9	7	2	knapweed
	6	42	6	3	0	
	7	47	13	25	0	
	8	53	19	25	1	clover
	9	60	4	5	0	
	10	66	5	3	0	
3	1	6	14	30	0	
	2	15	10	20	0	
	3	20	9	25	0	
	4	28	3	5	0	
	5	33	5	5	0	
	6	35	5	5	0	
	7	36	15	25	0	
	8	42	6	5	2	
	9	47	4	5	0	
	10	53	10	15	2	knapweed
4	1	14	26	40	0	
	2	17	57	75	0	
	3	21	60	85	0	
	4	23	38	50	0	
	5	28	18	30	0	
	6	36	10	25	0	
	7	44	44	80	0	
	8	45	12	25	0	
	9	54	26	55	2	thistle
	10	60	7	15		

5	1	7	12	25	0	
	2	13	4	5	0	
	3	17	4	2	0	
	4	18	6	12	0	
	5	23	1	2	0	
	6	32	4	8	0	
	7	39	3	8	0	
	8	42	6	12	0	
	9	50	8	10	0	
	10	60	0	0	0	

Plot Number	Frame Number	Tape Distance (feet)	Plant stems/ Frame (20x50 cm)	Aerial Cover		Comments
				% grass	% forbs	
6	1	5	2	0	1	75% rock
	2	12	2	<1	0	90% rock
	3	16	1	<1	0	80% rock
	4	23	3	<1	0	85% rock
	5	31	9	2	<0.5	50% rock
	6	35	3	<1	0	30% rock
	7	43	8	3	0	1 forb; 30% rock
	8	46	33	7	0	1 knapweed; 20% rock
	9	52	12	7	0	1 knapweed; 20% rock
	10	56	4	0	1	unk knapweed; 10% rock
7	1	13	31	15	0	30% rock
	2	15	25	15	0	
	3	19	16	10	0	
	4	21	24	15	0	
	5	29	33	20	0	
	6	32	24	25	0	30% rock
	7	38	13	20	0	30% rock
	8	40	9	5	0	
	9	42	20	5	1	knapweed
	10	50	16	32	3	knapweed
8	1	12	32	35	0	
	2	20	12	20	0	
	3	24	28	30	0	
	4	30	28	10	30	sweetclover
	5	34	12	7	0	
	6	41	22	30	5	
	7	45	24	35	5	knapweed
	8	52	33	40	18	unk forb, knapweed
	9	55	52	60	20	15 knapweed; 5 unk forb
	10	56	54	40	15	5 unk forb; 10 knapweed
9	1	11	31	35	0	15% rock
	2	15	30	35	0	
	3	20	31	20	0	
	4	28	39	35	<1	clover
	5	33	12	15	0	10% rock
	6	40	10	10	0	30% rock

	7	42	28	25	0	20% rock
	8	48	81	83	7	4 forbs, knapweed
	9	52	34	40	30	2 clover, knapweed
	10	54	43	50	45	knapweed
10	1	5	5	15	0	
	2	8	9	25	0	
	3	17	17	40	0	
	4	20	1	< 1	0	
	5	24	0	0	0	
	6	30	9	15	0	50% rock
	7	33	14	25	2	knapweed
	8	45	23	25	0	
	9	52	11	50	30	knapweed; 15% rock
	10	59	19	30	0	

Table A2.2 Erosion evaluation of U.S Highway 2 plots.

Plot Number	Erosion score *	Erosion ranking**	Comments
1	40	Slight	Very little plant litter, moderate amount of sediment movement observed at toe of plot
2	28	Slight	Limited amount of sediment movement observed at toe of plot
3	12	Stable	
4	6	Stable	Mineral soil rarely visible under compost blanket
5	6	Stable	Mineral soil rarely visible under compost blanket
6	0	Stable	Control plot, no compost
7	0	Stable	
8	0	Stable	Surface of the plot 75% rock > 2mm
9	0	Stable	Surface of the plot 30% rock, 70% compost
10	0	Stable	Surface of the plot 20% rock, 80% compost

* Erosion score is determined based on 100 point system developed by Clark (1980)—Erosion Condition Classification System, U.S. Dept. of Interior, BLM Technical Note 346.
**Stable=1-20 points, Slight=21-40 points, Moderate=41-60 points, Critical=61-80 points, Severe=81-100 points.